Optical Density Measurement for Absorbed Dose Estimation to Enhance Quality Assurance and Quality Control in Dental Radiography using Dental Radiographs

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Abstract

X – ray imaging and its application should be closely monitored and controlled, so that only safe amounts or doses is put to use at all times. This will guide against excess dose to patients or personnel during the cause of any exposure, as it is applied. This study presents the measurement of optical densities of dental radiographs, of two hospitals, namely St. Bridget hospital and University of Benin Teaching Hospital (UBTH), both in Benin City, Edo State, Nigeria, with the aid of a densitometer, model MA 5336. The measured optical densities were used to estimate the X – ray radiation absorbed dose to patients undergoing the dental X – ray, for the purpose of Quality Assurance (QA) and Quality Control (QC). Fifty (50) adult samples of dental radiographs were collected per hospital, making a total of one hundred (100) for both hospitals. The optical densities were measured five times at different spots across the image of each of the dental radiographs and the mean were obtained, in other to estimate the absorbed dose. The results obtained showed that for St. Bridget hospital, the mean dose was 0.041 mGy, minimum dose 0.002 mGy, maximum dose 0.0086 mGy, range of dose 0.084 mGy, SD 0.029, Kurtosis 1.423 mGy, 1st Q 0.009, 2nd 0.043 mGy and 3rd Q 0.0067. Results for UBTH showed that mean dose was 0.016 mGy, minimum dose 0.004 mGy, maximum dose 0.062 mGy, range of dose 0.058 mGy, SD 0.011, Kurtosis 6.628, 1st Q 0.008, 2nd Q 0.012 and 3rd Q 0.019. The results were in agreement with those of the International Atomic Energy Agency (IAEA) guidance levels, in X – ray guided medical interventional procedures.

Keywords: *Imaging, Dose, Absorbed Dose, Dental Radiographs, Optical Densities*

I. INTRODUCTION

The perception that medical imaging radiation may be harmful has been apparent for over 120 years [1]. This knowledge of radiation risk has evolved through three overlapping phases, namely local tissue damage, genetic changes and cancer [1]. In 1896, soon after Rontgen's discovery of X-rays, it was recognized that X-ray could cause skin burns and hair loss [2, 3]. In the late 1890's the surgeon general's report in the USA, described instances in which X-rays produced "strange burns" on the bodies of soldiers in the Spanish – America war [3]. Soon thereafter it was recognized that X-rays could cause sterility and limb tissue damage severe enough to require amputations [3]. At the time, not everyone believed that X-rays were the cause of the problems. The burns and other local effects were often attributed to non – X-rays causes such as personal idiosyncrasy or electrical current effects from generators [3]. In the 1920's, newly established societies such as the Rontgen Ray and the Radiology Society of North America, began working with X-ray equipment manufacturers and physicists to define units for measuring radiation; the Rontgen was defined in 1925 [3]. They then started to created standards "for safe level radiation" and produced guidelines for shielding both patients and X-rays workers [3]. In the early years, there was an additional social side effect of X-rays. There was major concern with an invasion of body privacy. People felt that there was a "revolting indecency by looking at other people's bones and penetrating the flesh of human woman". They felt that this was breaking down boundaries of privacy [2]. The second phase of the history of the harmful effects of radiation started in the 1920's and focused on genetic effects. This culminated when Herman Muller was awarded the Nobel Prize for showing that high radiation doses caused genetic mutations in the germ cells of fruits flies [3-6]. The third and final phase was the concern of the relationship between radiation exposure and cancer [7-9]. This can be separated into two distinct eras. From 1945 to 2000 the concern was predominantly with very high doses of radiation. Intense interest in cancer risk from high dose radiation started after the dropping of two atomic bombs on Japan in 1945

[3, 7-9]. The last 15 years, since 2001, have seen intense interest in cancer from low doses of radiation from medical imaging. Film based and digital intraoral imaging is one of the most popular diagnostic imaging systems in dentistry. Dental radiographs (often called X-rays) are an important part of your dental care. Along with an oral examination, they provide your dentist with a more complete view of what's happening in your mouth. A dental radiograph gives your dentist a picture of your hard tissues (teeth and bones) and the soft tissues that surround your teeth and jaw bones [10]. For example, dental radiographs may help your dentist see caries (tooth decay) that develops between the teeth or under restoration (fillings); diseases in the bone; periodontal (gum) disease; infections that develop under gums; some type of tumors. Dental radiographs can alert your dentist to changes in your hard and soft tissues. In children, radiographs allow the dentist to see how their teeth and jaw bones are developing. Like medical radiographs, dental radiographs allow your dentist to evaluate any injuries to your face and mouth [10]. Dental radiographs can help your dentist identify diseases and developmental problems before they become serious health issues. Early detection of an infection or injury also can limit or prevent further damage to other areas. Some people wonder if dental radiographs are safe because they expose the patient to radiation. Several factors and practices work together to make dental radiography safe. Dentists follow the ALARA principle, which stands for "As Low As Reasonably Achievable", when obtaining radiographs. This radiation safety principle limits your exposure by incorporating the following techniques; use the fastest image receptor (that is, the fastest film speed or digital speed); reduction in the size of the X-ray beam to the size of the image receptor whenever possible; use of proper exposure and processing techniques; use of leaded aprons and, whenever possible, thyroid collars [10]. If you are seeing a new dentist, be sure to provide him or her with copies of your existing radiographs to avoid duplicating them. This also will help limit your exposure to radiation [10]. Your dentist will decide when radiographs are needed on the basis of your oral examination findings, any symptoms you report, a review of your health history, your risk of experiencing oral disease, your age, or any combination of preceding. A dental staff member will place a leaded apron on your body during the procedure [10]. He or she also may place a leaded collar around your neck to shield your thyroid gland (located in your neck) but only if its use does not interfere with the procedure. The lead in the apron and collar shields your organs from radiation exposure [10]. Because of the low radiation dose associated with dental radiographs, people who have received radiation treatment for head and neck cancer can undergo dental radiography. In fact, head and neck radiation treatment can increase the risk of developing tooth decay, making the radiographs all the more important for these patients [10]. If you are pregnant tell your dentist. During your pregnancy, you may need to have radiographs taken as part of your treatment plan for a dental disease that requires immediate attention. Use of the leaded apron and collar will protect you and your fetus from radiation exposure [10]. In general medical exposure of man to ionizing radiation arises from practices such as diagnostic, therapeutic and nuclear medicine procedures. Consequently, the patients, medical radiation specialists and the general population receive significant exposure to ionizing radiation [11]. Medical exposure to radiation, from artificial or man-made radiation sources, contributes the largest components of radiation dose to general population [12]. It has also been estimated that diagnostic radiology and nuclear medicine procedures contribute 96% and 88% of dose to the collective effective dose from man – made sources of radiation in the United Kingdom [13] and United States of America [14] respectively.

II. MATERIALS AND METHOD

Samples of dental radiographs were collected from the University of Benin Teaching Hospital (UBTH) and St. Bridget Hospital radiological departments, both in Benin City, Edo State, Nigeria. The fundamental objectives of this research are to measure the optical densities of the dental radiographs and to estimate the absorbed dose to patients that underwent X – ray exposure in these hospitals. This is to check for standards of good practice as an aid to ensure strict adherence to Quality Assurance (QA) and Quality Control (QC), for dental X – ray diagnosis and radiography, so as to guide against over exposure or overdose of X – ray radiation. Radiographs from different examinations namely Skull (PA, AP, LAT. RT, LAT. LT) and MANDIBLE (PA, AP, LAT. LT, LAT. RT), were collected for use and the following abbreviations was adopted for the purpose of this study:

PA: Posterior Anterior
AP: Anterior Posterior
LAT. RT: LATERAL RIGHT
LAT. LT: LATERAL LEFT
MAND. : MANDIBLE
Absorbed X – ray dose: X
Net optical density: NOD
Mean optical density: MOD
Mean Optical Density: D_{MOD}
Optical density: OD or D
Measured optical densities: OD_1, OD_2, OD_3, OD_4 and OD_5
Standard deviation: SD
Minimum absorbed dose: X_{Min}
Maximum absorbed dose: X_{Max}
First Quartile: 1^{st} Q
Second Quartile: 2^{nd} Q
Third Quartile: 3^{rd} Q
Film Serial Number: FILM S/N

TABLE 1. Features of the densitometer (Gammex, 2016) [15]

Model MA 5336 (made in USA by GAMMEX)	Features
Range	0 to 4.0 optical density
Accuracy	± 0.02 density
Reproducibility	± 0.01 density
Warm up time	None
Measuring area	2mm diameter and 1mm diameter
Power supply	Four rechargeable AA NiCad batteries, 4.8V total rated at 600mAh (included)
Battery charger	SE 30 – 45 (115 VAC) or SE – 30 (230 VAC) 50 to 60 Hz
Charge time	Approximately 14 hours
Size	5.08 X 7.46 X 17.8 cm (2 X 2.9 X 7 in)
Weight	0.7 Kg (1.5 lbs.)

A film densitometer, model MA 5336 for the measurement of optical density was used. The light source / detector assembly is driven in finite incremental steps and resolution over the entire scanning area to ensure precise positioning with a high degree of repeatability [16]. The film densitometer is a simple to use peripheral device for the measurement of the blackening density film exposed to ionizing radiation. Since X-ray image on the film is a black and white image with various blackening densities, the densitometer accepts standard X-ray films [16].

The optical densities of each dental radiograph, was measured repeatedly five times at different spots on each image of the film as optical densities OD_1, OD_2, OD_3, OD_4 and OD_5. The average of the five optical densities was then taken to obtain the MOD. The optical densities were converted to the absorbed X-ray radiation doses X, in milli gray (mGy), which is the amount of X-ray radiation dose that each patient was exposed to. The mean absorbed dose, range of absorbed dose, standard deviation, kurtosis, first and third quartiles were also calculated for the samples.

The blackening of the film after X-ray radiation exposure is expressed in terms of its optical density as [17]:

$$D = \log_{10}\left(\frac{I_o}{I}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where I_o and I is the light intensities before and after passing the exposed film material. Optical density is a numerical value indicating the degree of blackening on an X-ray radiographic film. The correlation between the optical density D and the maximum number of sensitized grains results in a relation between the optical density D and the absorbed dose X. Thus:

$$D = D_{max}[1 - e^{-kX}] \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where,

D_{max} = 4 (this is the maximum measurable OD obtainable with the densitometer) [17],

k = 9.36 (k is a conversion constant) [17].

Therefore, Equation (2) for the measured optical density becomes:

$$D = 4[1 - e^{-9.36X}] \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Solving Equation (3) for the absorbed X-ray radiation dose X, gives:

$$X = \left(-\frac{1}{9.36}\right)\log_e\left(1 - \frac{D_{MOD}}{4}\right) \ldots\ldots\ldots (4)$$

Equation (4) was used to convert the measured optical densities of the dental radiographs to absorbed X-ray radiation dose, in milli gray (mGy).

III. RESULTS AND DISCUSSION

The results obtained in this work are presented in Tables 2, 3 and 4, for the dental radiographs examinations.

TABLE 2. St. Bridget hospital measured dental radiographs OD, NOD and MOD

HOSPITAL NAME	FILM S/N	EXAMINATIONS	MEASUREMENTS					NOD	MOD
			OD_1	OD_2	OD_3	OD_4	OD_5		
ST. BRIDGET X-RAY CLINIC	1	SKULL:PA	3.40	0.40	0.43	0.10	0.64	4.97	0.99
	2	SKULL: AP	0.47	0.17	0.38	0.09	0.09	1.20	0.24
	3	SKULL: LAT. RT	0.01	0.27	0.41	0.17	0.19	1.05	0.21

	4	SKULL: PA	0.26	0.17	0.39	0.21	0.27	1.30	0.26
	5	SKULL: PA	0.48	0.46	0.56	0.20	1.63	3.33	0.67
	6	SKULL: AP	0.13	0.26	0.43	0.08	0.29	1.19	0.24
	7	SKULL: LAT. RT	0.06	0.36	0.53	0.36	0.23	1.54	0.31
	8	SKULL: LAT. LT	0.05	0.25	0.29	0.13	0.90	1.62	0.32
	9	SKULL: PA	0.08	0.11	0.39	0.55	0.12	1.25	0.25
	10	SKULL: AP	0.25	0.23	0.24	0.12	0.07	0.91	0.18
	11	SKULL: LAT. LT	0.08	0.15	0.09	0.41	0.16	0.89	0.18
	12	SKULL: PA	0.18	0.71	0.28	0.46	0.04	1.67	0.33
	13	SKULL: LAT. RT	0.26	0.24	0.29	0.11	0.28	1.18	0.24
	14	SKULL: LAT. LT	0.04	0.17	0.08	0.01	0.10	0.40	0.08
	15	SKULL: AP	0.01	0.05	0.25	0.29	0.20	0.80	0.16
	16	SKULL: PA	0.30	0.37	0.08	0.01	0.10	0.86	0.17
	17	SKULL: AP	0.31	0.54	0.56	0.52	0.56	2.49	0.50
	18	SKULL: LAT. LT	0.17	0.59	0.73	0.41	0.24	2.14	0.43
	19	SKULL: LAT. RT	0.26	0.21	0.39	0.25	0.18	1.29	0.26
	20	MAND.: LAT. LT	2.07	0.80	1.75	1.75	1.98	8.35	1.67
	21	MAND.: LAT. RT	1.66	1.41	1.47	1.33	1.83	7.70	1.54
	22	SKULL: PA	2.43	2.27	2.20	2.29	1.81	11.00	2.20
	23	SKULL: PA	2.68	1.92	0.25	1.15	1.29	7.29	1.46
	24	MAND.: LAT. RT	0.86	0.99	1.64	1.54	1.57	6.60	1.32
	25	MAND.: LAT. LT	1.13	0.89	0.54	0.29	0.48	3.33	0.67
	26	MAND.: PA	0.85	1.49	1.46	1.25	1.27	6.32	1.26
	27	MAND.: LAT. LT	2.20	2.17	1.98	2.14	2.28	10.77	2.15
	28	MAND.: LAT. RT	1.89	2.26	1.93	2.13	2.10	10.31	2.06
	29	SKULL: PA	2.31	2.07	2.35	2.22	2.12	11.07	2.21
	30	SKULL: PA	1.62	1.50	1.35	1.17	0.98	6.62	1.32
	31	MAND.: LAT. LT	2.16	2.16	2.25	1.45	1.91	9.93	1.99
	32	MAND.: LAT. RT	1.69	1.94	1.37	2.18	1.96	9.14	1.83
	33	MAND.: PA	1.03	1.29	2.15	1.55	1.68	7.70	1.54
	34	MAND.: LAT. LT	0.50	1.16	1.27	1.34	1.25	5.52	1.10
	35	MAND.: LAT. RT	0.55	1.52	1.28	1.79	0.87	6.01	1.20
	36	SKULL: & MAND.	1.35	1.36	0.59	0.52	0.64	4.46	0.89
	37	SKULL: & MAND.	1.98	2.07	1.84	1.63	1.83	9.35	1.87
	38	SKULL: AP	2.12	2.07	1.23	1.75	1.80	8.97	1.79
	39	SKULL: LAT. LT	1.76	1.73	1.90	1.46	1.49	8.34	1.67
	40	SKULL: LAT. LT	1.97	2.10	2.09	2.02	1.23	9.41	1.88
	41	SKULL: PA	2.10	2.27	2.16	2.09	2.11	10.73	2.15

	42	SKULL: AP	1.75	1.96	1.92	1.68	1.76	9.07	1.81
	43	MAND.: LAT. RT	2.14	1.66	1.97	2.18	1.90	9.85	1.97
	44	MAND.: LAT. LT	2.05	2.07	1.81	1.81	2.16	9.90	1.98
	45	MAND.: PA	2.27	1.97	2.08	1.68	1.78	9.78	1.96
	46	MAND.: LAT. LT	1.60	1.06	1.20	1.57	1.11	6.54	1.31
	47	MAND.: LAT. RT	1.90	1.84	1.99	2.13	1.96	9.82	1.96
	48	MAND.: PA	1.97	1.94	1.60	1.85	1.74	9.10	1.82
	49	MAND.: PA	2.38	1.78	2.06	1.78	1.87	9.87	1.97
	50	SKULL & MAND.	1.67	1.68	1.64	1.90	1.90	8.79	1.76

In Table 2, the measured optical densities varied across the image of the dental radiographs during the measurements. This is expected, as the thickness and density of the tissues and bones involved varies for each dental radiographs. The average of the measured OD's is thus taken to be the mean optical density (MOD). Min OD 0.01, Max OD 3.40, Min NOD 0.40, Max NOD 11.07, Min MOD 0.08 and Max MOD 2.21. Table 3 represents the UBTH measured dental radiographs OD, NOD and MOD.

TABLE 3. UBTH measured dental radiographs OD, NOD and MOD

HOSPITAL NAME	**FILM S/N**	**EXAMINATIONS**	**MEASUREMENTS**					**NOD**	**MOD**
			OD_1	OD_2	OD_3	OD_4	OD_5		
UBTH	1	SKULL: LAT. LT	0.82	0.31	0.27	0.63	0.10	2.13	0.43
	2	SKULL: PA	0.28	0.29	0.23	0.34	0.23	1.37	0.27
	3	SKULL: PA	2.02	2.19	0.79	2.55	1.26	8.81	1.76
	4	SKULL: PA	0.43	0.29	0.10	0.70	0.72	2.24	0.45
	5	SKULL: LAT. RT	0.50	0.37	0.09	1.23	0.76	2.95	0.59
	6	SKULL: LAT. LT	0.62	0.77	1.35	0.38	0.87	3.99	0.80
	7	SKULL: LAT. RT	0.47	0.48	0.30	0.41	0.34	2.00	0.40
	8	SKULL: PA	0.31	0.21	0.20	0.13	0.19	1.04	0.21
	9	SKULL: AP	0.71	1.10	1.54	1.13	1.39	5.87	1.17
	10	SKULL: PA	2.64	0.64	0.01	1.23	1.21	5.73	1.15
	11	SKULL: LAT. LT	0.42	0.47	0.94	0.38	1.79	4.00	0.80
	12	SKULL: LAT. RT	1.12	0.73	0.99	1.68	1.53	6.05	1.21
	13	SKULL: LAT. LT	0.37	0.67	0.89	0.47	0.11	2.51	0.50
	14	SKULL: PA	1.30	0.12	0.30	0.62	0.70	3.04	0.61
	15	SKULL: AP	0.38	0.45	0.51	0.36	0.50	2.20	0.44
	16	SKULL: LAT. RT	1.13	0.48	0.54	0.33	0.51	2.99	0.60
	17	SKULL: PA	0.36	0.10	0.54	0.44	1.74	3.18	0.64
	18	SKULL: LAT. RT	0.45	0.11	0.45	0.25	0.10	1.36	0.27
	19	SKULL: PA	0.44	1.96	0.15	0.20	0.93	3.68	0.74
	20	SKULL: LAT. LT	0.90	0.27	0.07	0.26	1.98	3.48	0.70
	21	SKULL: PA	0.36	0.26	0.48	0.32	0.30	1.72	0.34

	22	SKULL: AP	0.18	1.46	0.28	0.17	0.25	2.34	0.47
	23	SKULL: LAT. RT	0.66	0.45	0.36	0.10	0.01	1.58	0.32
	24	SKULL: LAT. LT	0.58	0.06	0.20	0.11	0.26	1.21	0.24
	25	SKULL: LAT. RT	0.24	0.27	0.10	0.47	0.93	2.01	0.40
	26	MAND.: PA	0.19	0.45	0.34	0.69	0.10	1.77	0.35
	27	MAND.: LAT. LT	0.07	0.08	0.15	0.54	0.39	1.23	0.25
	28	MAND.: LAT. RT	0.65	0.05	0.19	0.82	0.23	1.94	0.39
	29	SKULL: PA	0.11	0.65	0.03	0.04	0.36	1.19	0.24
	30	SKULL: LAT. RT	0.01	0.30	0.06	0.44	2.73	3.54	0.71
	31	SKULL: PA	0.17	0.22	0.25	0.29	0.01	0.94	0.19
	32	MAND.: PA	0.23	0.65	0.51	0.23	0.18	1.80	0.36
	33	MAND.: AP	0.12	0.22	0.37	0.22	0.05	0.98	0.20
	34	SKULL: PA	0.18	0.28	0.01	0.09	0.23	0.79	0.16
	35	SKULL: PA	0.66	0.44	0.38	0.30	0.39	2.17	0.43
	36	SKULL: AP	0.53	0.52	0.33	0.19	0.39	1.96	0.39
	37	SKULL: LAT. LT	0.61	0.48	0.61	0.24	0.40	2.34	0.47
	38	SKULL: LAT. RT	0.61	0.59	0.13	0.31	0.52	2.16	0.43
	39	MAND.: PA	0.89	0.71	0.13	2.83	0.78	5.34	1.07
	40	MAND.: LT	0.66	0.07	0.08	0.04	1.15	2.00	0.40
	41	MAND.: RT	0.43	1.10	0.05	0.19	0.89	2.66	0.53
	42	SKULL: AP	0.79	0.11	0.19	0.30	0.02	1.41	0.28
	43	SKULL: LAT. LT	0.48	0.81	1.89	0.56	1.73	5.47	1.09
	44	SKULL: PA	0.15	0.03	0.11	0.44	0.12	0.85	0.17
	45	SKULL: LAT. RT	0.65	0.05	0.58	0.32	1.03	2.63	0.53
	46	SKULL: PA	0.58	1.20	0.53	1.65	1.41	5.37	1.07
	47	SKULL: LAT. LT	0.48	0.69	0.33	0.04	0.33	1.87	0.37
	48	SKULL: PA	2.47	0.84	0.50	0.51	0.75	5.07	1.01
	49	SKULL: LAT. LT	0.82	0.31	0.27	0.63	0.10	2.13	0.43
	50	SKULL: PA	0.28	0.29	0.23	0.34	0.23	1.37	0.27

In Table 3, the variations occur throughout the films in terms of the measured OD, calculated NOD and NOD. The Min OD 0.01, Max OD 2.83, Min NOD 0.79, Max NOD 8.81, Min MOD 0.16 and Max MOD 1.76. Table 4 presents the estimated absorbed dose X, for both hospitals, for the various examinations.

TABLE 4. Estimated absorbed dose X for both hospitals

HOSPITAL NAME	FILM S/N	EXAMINATIONS	ESTIMATED DOSE X (mGy)	HOSPITAL NAME	FILM S/N	EXAMINATIONS	ESTIMATED DOSE X (mGy)
ST. BRIDGET X-RAY	1	SKULL:PA	0.031	UBTH	1	SKULL: LAT. LT	0.012

CLINIC							
	2	SKULL: AP	0.007		2	SKULL: PA	0.008
	3	SKULL: LAT. RT	0.006		3	SKULL: PA	0.062
	4	SKULL: PA	0.007		4	SKULL: PA	0.013
	5	SKULL: PA	0.019		5	SKULL: LAT. RT	0.017
	6	SKULL: AP	0.007		6	SKULL: LAT. LT	0.024
	7	SKULL: LAT. RT	0.009		7	SKULL: LAT. RT	0.011
	8	SKULL: LAT. LT	0.009		8	SKULL: PA	0.006
	9	SKULL: PA	0.007		9	SKULL: AP	0.037
	10	SKULL: AP	0.005		10	SKULL: PA	0.036
	11	SKULL: LAT. LT	0.005		11	SKULL: LAT. LT	0.024
	12	SKULL: PA	0.009		12	SKULL: LAT. RT	0.038
	13	SKULL: LAT. RT	0.006		13	SKULL: LAT. LT	0.014
	14	SKULL: LAT. LT	0.002		14	SKULL: PA	0.018
	15	SKULL: AP	0.004		15	SKULL: AP	0.012
	16	SKULL: PA	0.005		16	SKULL: LAT. RT	0.017
	17	SKULL: AP	0.014		17	SKULL: PA	0.019
	18	SKULL: LAT. LT	0.012		18	SKULL: LAT. RT	0.008
	19	SKULL: LAT. RT	0.007		19	SKULL: PA	0.022
	20	MAND.: LAT. LT	0.058		20	SKULL: LAT. LT	0.020
	21	MAND.: LAT. RT	0.052		21	SKULL: PA	0.010
	22	SKULL: PA	0.085		22	SKULL: AP	0.013
	23	SKULL: PA	0.048		23	SKULL: LAT. RT	0.009
	24	MAND.: LAT. RT	0.043		24	SKULL: LAT. LT	0.007
	25	MAND.: LAT. LT	0.019		25	SKULL: LAT. RT	0.011
	26	MAND.: PA	0.041		26	MAND.: PA	0.010
	27	MAND.: LAT. LT	0.083		27	MAND.: LAT. LT	0.007
	28	MAND.: LAT. RT	0.077		28	MAND.: LAT. RT	0.011
	29	SKULL: PA	0.086		29	SKULL: PA	0.007
	30	SKULL: PA	0.043		30	SKULL: LAT. RT	0.021
	31	MAND.: LAT. LT	0.073		31	SKULL: PA	0.005
	32	MAND.: LAT. RT	0.065		32	MAND.: PA	0.010

	33	MAND.: PA	0.052		33	MAND.: AP	0.005
	34	MAND.: LAT. LT	0.035		34	SKULL: PA	0.004
	35	MAND.: LAT. RT	0.038		35	SKULL: PA	0.012
	36	SKULL: & MAND.	0.027		36	SKULL: AP	0.011
	37	SKULL: & MAND.	0.067		37	SKULL: LAT. LT	0.013
	38	SKULL: AP	0.064		38	SKULL: LAT. RT	0.012
	39	SKULL: LAT. LT	0.058		39	MAND.: PA	0.033
	40	SKULL: LAT. LT	0.068		40	MAND.: LT	0.011
	41	SKULL: PA	0.082		41	MAND.: RT	0.015
	42	SKULL: AP	0.065		42	SKULL: AP	0.008
	43	MAND.: LAT. RT	0.072		43	SKULL: LAT. LT	0.034
	44	MAND.: LAT. LT	0.073		44	SKULL: PA	0.005
	45	MAND.: PA	0.072		45	SKULL: LAT. RT	0.015
	46	MAND.: LAT. LT	0.042		46	SKULL: PA	0.033
	47	MAND.: LAT. RT	0.072		47	SKULL: LAT. LT	0.010
	48	MAND.: PA	0.065		48	SKULL: PA	0.031
	49	MAND.: PA	0.073		49	SKULL: LAT. LT	0.012
	50	SKULL & MAND.	0.062		50	SKULL: PA	0.008

Table 4 presents the results of the estimated doses for both hospitals and the occurrence of variations in the estimated absorbed doses can be seen. This is due to the fact that the tissues and tissues densities were not the same for patients undergoing the dental examinations or screening. For St. Bridget hospital, the Min X 0.002, Max X 0.086 and for UBTH, the Min X 0.004, Max 0.062. The estimated absorbed doses are in agreement with those of the International Atomic Agency (IAEA), guidance levels in X-ray guided medical interventional procedures [18]. Table 5 represents the descriptive statistics of the mean dose of the two hospital samples.

TABLE 5. Descriptive statistics of the estimated mean dose X (mGy) for the dental radiographs

Hospitals	**Mean dose**	**Min**	**Max**	**Range**	**SD**	**Kurtosis**	**1st Q**	**2nd Q**	**3rd Q**	**Skewness**
St. Bridget	0.041	0.002	0.086	0.084	0.029	1.423	0.009	0.043	0.067	0.011
UBTH	0.016	0.004	0.062	0.058	0.011	6.628	0.008	0.012	0.019	1.787

In Table 5 for St. Bridget hospital, Mean dose 0.041, Min dose 0.002, Max dose 0.086, Range 0.084, SD 0.029, Kurtosis 1.423, 1st Q 0.009, 2nd Q 0.043, 3rd Q 0.067 and Skewness 0.011. For UBTH, Mean dose 0.016, Min dose 0.004, Max dose 0.062, Range 0.058, SD 0.011, Kurtosis 6.628, 1st Q 0.008, 2nd Q 0.012, 3rd Q 0.019 and Skewness 1.787. The Min and Max dose of the dental radiographs samples for the two hospitals depicts a good trend in the exposure level to patients during diagnosis and screening. The Range was also close to the Max dose, which gives an agreement to the dosage exposures across the patients and the hospitals. The SD was found to be less enough, which depicts that the estimated dose values are not too far from the Mean dose as a reference value and this gives an account for good measurement throughout the research. The Kurtosis value shows a normal distribution of the accuracy of the OD measurements and the estimated dose across the dental radiograph samples, that is, the normal distribution is a symmetrical distribution with well-behaved tails. The 1st Q is the median of the lower half of the data set. This means that about 25% of the dose lie below Q_1 and about 75% lie above Q_1. The 2nd Q is the median, this divides the data range in the middle and has 50% of the data below it and the remaining 50% of the data range above it. The 3rd Q is the median of the upper half of the data set. This means that about 75% of the doses lie below Q_3 and about 25% lie above Q_3. These results in Table were in good agreement with the Nigerian Basic Ionizing Radiation Regulation (NBIRR) [19] and the International Commission on Radiological Protection (ICRP) [20].The figures represent the plots and the results of MOD against the X, for the two hospitals, from a curve fitting using the MATLAB.

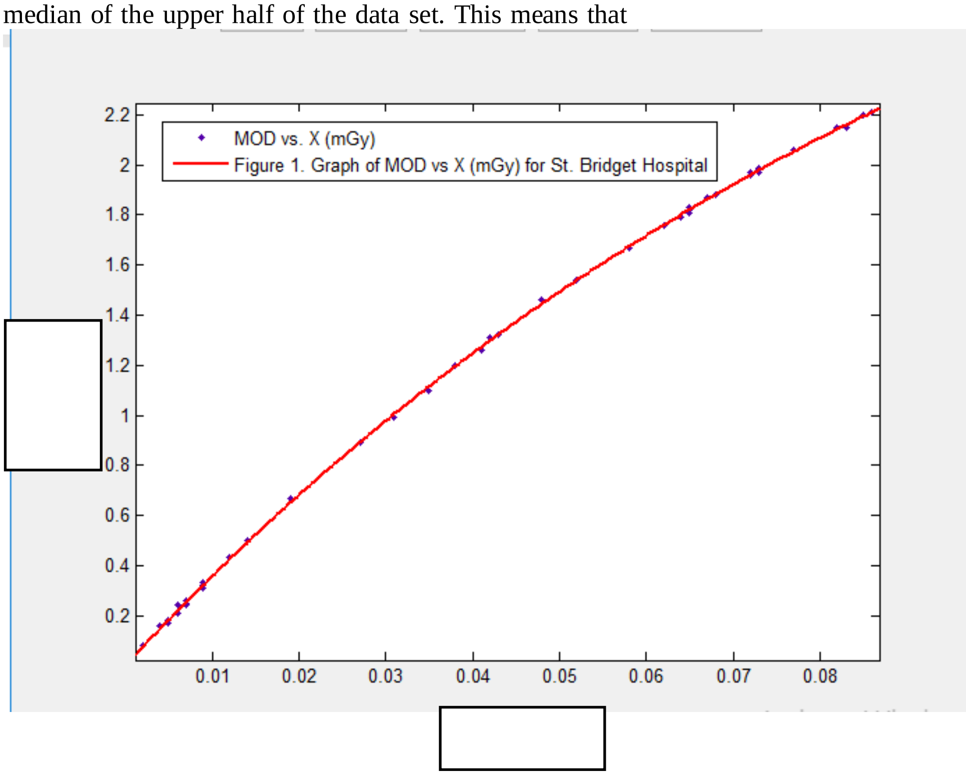

Fig 1: Graph of MOD vs X (mGy) for St. Bridget Hospital

Results

```
General model:
      f(x) = Dmax*[1-exp(-k*x)]
Coefficients (with 95% confidence bounds):
      Dmax =       4.019  (3.923, 4.114)
      k =       9.293  (8.991, 9.595)

Goodness of fit:
  SSE: 0.004508
  R-square: 0.9998
  Adjusted R-square: 0.9998
  RMSE: 0.009691
```

Fig 2: Results of the curve fitting for St. Bridget Hospital

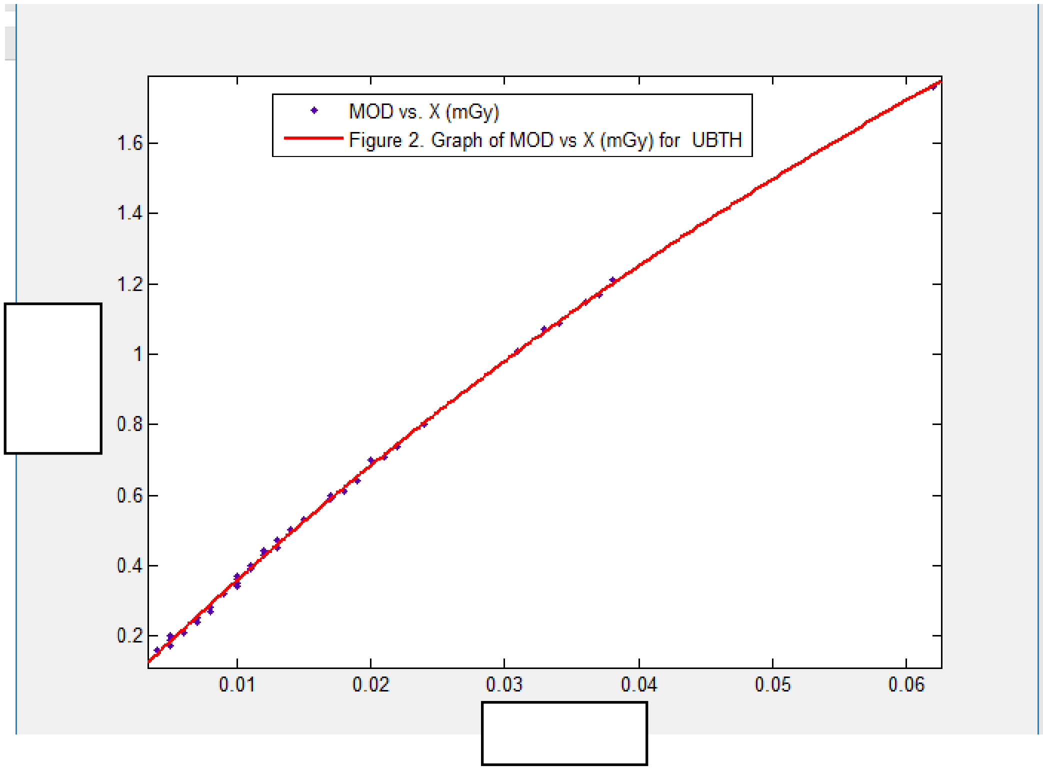

Fig 3: Graph of MOD vs X (mGy) for UBTH

Results

```
General model:
       f(x) = Dmax*[1-exp(-k*x)]
Coefficients (with 95% confidence bounds):
       Dmax =        4.003  (3.777, 4.229)
       k =        9.376  (8.764, 9.988)

Goodness of fit:
  SSE: 0.004417
  R-square: 0.9992
  Adjusted R-square: 0.9992
  RMSE: 0.009799
```

Fig 4: Results of the curve fitting for UBTH

Figures of the MOD vs X (mGy) for the two hospitals show a good exponential trend in the measured OD and the estimated dose. The higher the OD value, the greater the amount of estimated dose. Results of the fit for St. Bridget hospital, contains the General model f(x), used in estimating the doses, Coefficients (with 95% confidence bounds) as D_{max} fixed at 4.019, interval of between 3.923 to 4.114 and k fixed at 9.293, interval between 8.991 to 9.595. The Goodness of fit has; Sum of Squares due to Error (SSE) 0.004508, which is close to 0, indicating that the model has a smaller random error component and the fit will be more useful for prediction. R- square 0.9998, a value close to 1, indicating a greater proportion of variance accounted for by the model. Adjusted R – square

0.9998, this is closer to 1, indicating a better fit. Root Mean Square Error (RMSE) 0.009691, this is close to 0, which indicates a fit that is more useful for prediction. Also the results of the fit for UBTH, contains the General model f(x), used in estimating the doses, Coefficients (with 95% confidence bounds) as D_{max} fixed at 4.003, interval of between 3.777 to 4.229 and k fixed at 9.376, interval of between 8.764 to 9.988. The Goodness of fit has; Sum of Squares due to Error (SSE) 0.004417, random error component, and the fit will be more useful for prediction. R – square 0.9992, a value close to 1, indicating that a greater proportion of variance is accounted for by the model. Adjusted R – square 0.9992, this is close to 1, indicating a better fit. Root Mean Square due to Error (RMSE) 0.009799, this is close to 0, which indicates a fit that is more useful for prediction.

IV. CONCLUSION

In Tables 2 and 3, the MOD can be seen to vary from one film to the other. The higher the MOD, the greater the value of the estimated dose, as shown in Table 4, for both hospitals. This depicts a good trend in the dosage application to patients undergoing diagnosis and treatment. It is however important that ALARA (as low as reasonably achievable) principle of X-ray radiation dose be used for the purpose of dental diagnosis and treatment. Even those who believe that imaging radiation has a long – term risk of cancer, concede that this risk is extremely small. It is suggested that leading radiology, health physics and other medical societies, publish position statements to educate physicians and patients regarding the possibility risks of cancer from medical imaging radiation. The QA and QC approach to screening, diagnosis and treatment dosage usage in dental radiography can thus be derived from this work, to safeguard against excess dose or injury to patients and personnel.

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REFERENCES

[1] Cohen, MD. (2018). Is there a risk of getting cancer from radiation from medical diagnostic imaging? J Radiol Med Imaging. 2018; 1: 1005 2018; 1: 1005.

[2] Sansare K, Khanna V, Karjodkar F. (2011). Early victims of X-rays: a tribute and current perception DentomaxillofacRadiol.2011; 40: 123 – 125.

[3] Kevles BH. (1997). Naked to the bone. Rutgers University Press. New Brunswick. New Jersey. 1997; 46 – 48.

[4] Muller HJ, Mott – smith M. (1930). Evidence that natural radioactivity is inadequate to explain the frequency of "natural" mutations. Genetics. 1930; 16: 277 – 285.

[5] Muller HJ. (1946). Nobel Prize Lecture. Stockholm, Sweden. 1946.

[6] Carlson EA. (2009). Biographical Memoir Herman Joseph Muller 1890 – 1967. National Academy of Sciences 2009.

[7] Editorial A nuclear shadow from Hiroshima and Nagasaki to Fukushima Lancet. (2015); 403.

[8] Clancey G, Chhem R. (2015). Hiroshima, Nagasaki and FukushimaLancet. (2015); 386: 405 – 406.

[9] Cutter JM. (2014). Leukemia incidence of 96,000 Hiroshima atomic bomb survivors is compelling evidence that the LNT model is wrong. Arch Toxicol. 2014; 88: 847 – 848.

[10] American Dental Association (2011). Dental radiographs. Benefits and Safety. JADA 142 (9), September, 2011. 1101.

[11] Akinlade BI, Odefemi FB, Farai IP. (2016). Overview of radiation dose to patients from medical X-ray examinations in Nigeria. Afr. J. Med. Sci.

[12] Hart D, Hiller MC, Shrimpton P. (2010). Doses to patients from radiographic and fluoroscopic X-ray imaging procedures in the UK – 2010 review. HPA – CRCE – 034, Chilton, Didcot, Oxfordshire OX11 ORQ.

[13] NRPB (National Radiological Protection Board). (2002). Radiation exposure of the UK population from medical and dental X-ray examinations. NRPB W-4 2002; Chilton, Didcot, Oxon OX11 ORQ.

[14] NCRP (National Council on Radiation Protection and Measurement). (1987).Ionizing radiation exposure of the population of the United States. NCRP 1987, Report 93.

[15] GAMMEX. (2016). Film Densitometer Peripheral Technical Manual, Model 5336. GAMMEX Middleton, WI, USA.

[16] Scarlart F, Scarsoreamu A, Oane M, Mtre E, Badita E. (2008). Determination of Absorbed Dose Using a Dosimetric Film. IX Radiation Physics & Protection Conference, 15 – 19 November, 2008. Nasr City, Egypt, 313 – 321.

[17] Artur T. (2003). Determination of Absorbed X-ray Radiation Dose in X-ray Diagnostics and Imaging. J. Med. Sci. 1 (2); 31 – 36.

[18] IAEA (International Atomic Energy Agency). (Safety Reports Series No 59).Establishing Guidance Levels in X-ray Guided Medical International Procedures: A pilot study. Safety Report Series No 59.

[19] NBIRR (Nigeria Basic Ionizing Radiation Regulation). (2003).

[20] ICRP (International Commission on Radiological Protection). (1996) Radiological Protection and Safety in Medicine, Publication 73 (Oxford and New York: Pergamon Press).